Human Exploration Enabling Robotic Systems and Technologies

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Introduction

- Infrastructure-driven Systems/Technologies
- Science-driven Systems/Technologies
- Integrated Systems
- Conclusions

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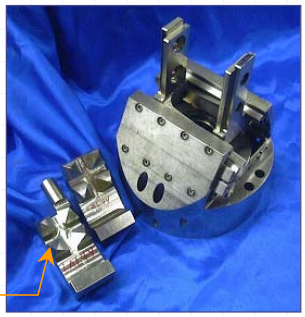
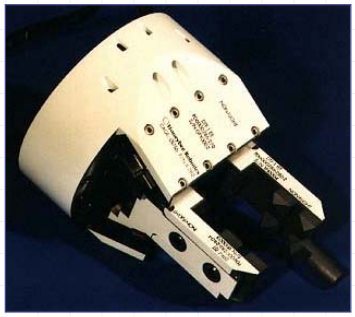
Infrastructure-driven Systems/Technologies

- Orbital systems
  - Construction and maintenance
  - Assistance for space flights
  - Improving the safety and productivity of the crew
- Planetary surface systems
  - Reconnaissance for identifying suitable locations for bases
  - Construction and maintenance of facilities
- Design Philosophy
  - Careful design of task-oriented, interchangeable end effectors
  - Simplifies telerobotic systems
  - Reduces the complexity of control systems
  - Reduces the amount of training and system/task-specific knowledge an operator requires
  - Reliable and robust connectors that allow the transfer of data and power are needed

End Effectors: FTS Gripper

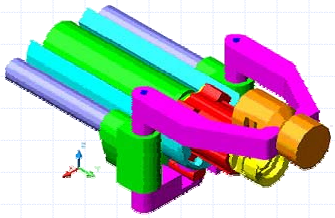
- Developed for Space Station Freedom's Flight Telerobotic Servicer
- Allows a telerobotic arm to manipulate specific objects
- 'Fingers' are easily changed out for any number of task-specific end pieces





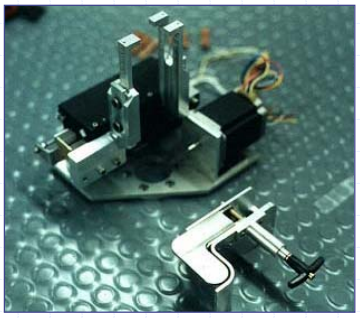
End Effectors: LaRC Truss Assembly

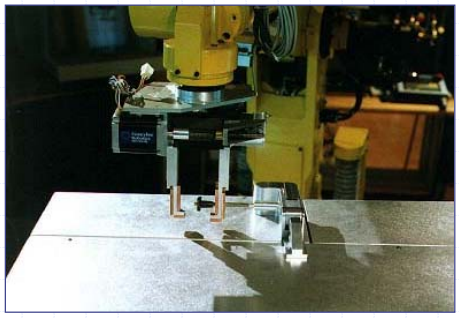
- For installation of strut members in large space truss structures
- Allows the assembly of precision, doubly-curved truss structures
- Capable of the complete installation and removal of varying length struts, including locking the joint connector
- Capable of removing and inserting the struts into storage trays for delivery to the assembly site
- **On-board** machine vision system is used to position the LaRC EE.
- 'Smart' end effector takes precision alignment out of high-level control system requirements



End Effectors: HST Toolbox Aide

- Developed to aid EVA for Hubble Space Telescope repair and maintenance
- Engages toolbox latch, releases the locking mechanism and then opens the toolbox door to allow access by astronauts.





Connectors: WAM/WAF

- The Robotic On-Orbit Worksite Attachment Mechanism/Worksite Attachment Fixture (WAM/WAF) originally designed for the Flight Telerobotic Servicer
- For use on space station or other large orbiting platforms

Connectors: ORU

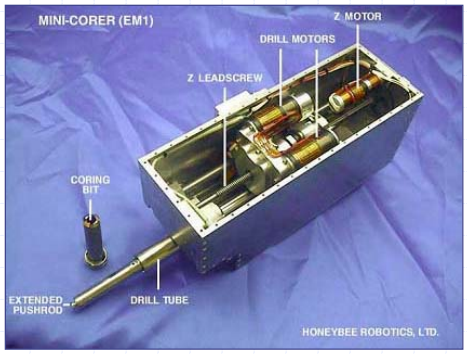
- Robotic Orbital Retrieval Unit (ORU) Fastening System
- Designed for astronaut EVA and robotic use
- Provides both mechanical and electrical connection from robot to ORU to platform
- Ability to fully mate with the platform site before disengagement with the robotic arm -- provides fault tolerance for inadvertent release.

Science-driven Systems/Technologies

- Assist in scientific studies when human exploration is underway,
- Greatly reduce risk and increasing science yield of missions
- Perform specific tasks autonomously – tasks that require high precision and need to be performed many times
- Improve the efficiency of human explorers, working when humans are acclimatizing, sleeping or involved in other activities
- Ensure pristine material samples for scientific study
- Reduce risk of biohazard exposure to human explorers

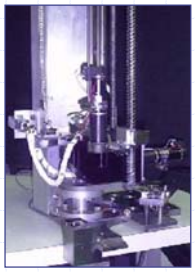
Mini-Corer: Near-surface Sampling

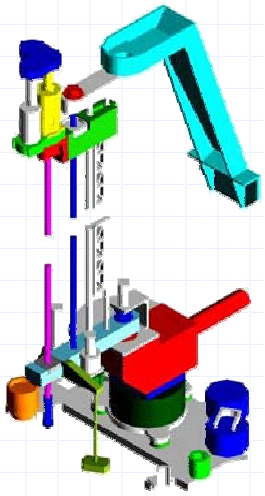
- Autonomous miniature rock core acquisition and transfer system
- Designed as a part of the Athena Mission
- Acquire rock cores for in-situ examination by other instruments and to provide for precision caching of the acquired cores for sample return
- Serves as a diagnostic by correlating drilling sensor data (torque, thrust, penetration rate) to terrestrial analogs to determine rock characteristics such as compressive strength and density



SATM: Sample Acquisition & Transfer Mechanism

- Robotic sampling system that interfaces with in-situ science instruments and sample return containers.
- Acquires surface/subsurface, unconsolidated/consolidated samples of very high compressive strengths, without cross contamination.
- A drill tip that can be used as a tool to open and close the sample return container, eliminating the need for a separate mechanism



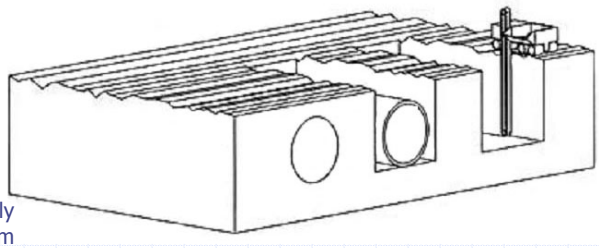


Multifunctional Systems: Mini-Corer Scooper

- Simple bit change-outs for drilling systems allow a variety of tasks to be performed by one robotic tool
- Allows for multiple bits with varying functions to be used interchangeably, dramatically increasing the functionality of this robotic system.
- Mini-Corer drill can acquire a soil acquisition end-effector; no additional actuators are required
- Mini-Corer can also acquire a rock abrasion tool to grind away the surface rind of rock, and allow examination of fresh rock by human explorers and/or in-situ instruments

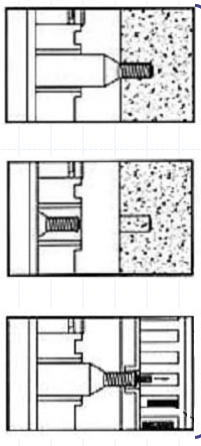
Integrated Systems

- In practice functionally-integrated systems may be the most practical and cost-effective
- For example, the Excavator is a telerobotic rover that may function as a trench-digging machine that simultaneously performs subsurface analysis as well as precision sample acquisition and transfer.



The Excavator working purely as an excavation system

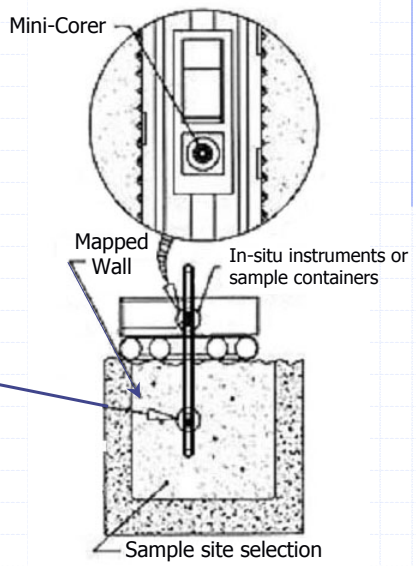
Excavator



Once predetermined depth is reached, core sample is broken off from regolith or rock

Mini-Corer is retracted with core sample secured within

Mini-Corer moves to surface, docks with sample return canister or in-situ instruments, and ejects core sample



Conclusions

- Directing design efforts to task-oriented end-effectors will significantly simplify robotic systems (LaRC Truss End-Effector, WAM/WAF)
  - Interchangeable, Multi-functional
  - Less complex control systems
  - Avoids high levels of training and system-specific skills for operators
- Leverage the extensive design efforts that have already gone into remote science studies to aid human explorers (MiniCorer, SATM)
  - Reduces (biohazard/exposure) risk to human explorers
  - Increases science yield of missions - working when humans are acclimatizing, sleeping or involved in other activities
  - Ensures the collection and study of pristine samples.
- Integrating infrastructure-related functions with scientific study capabilities may increase cost-effectiveness of human exploration in the Solar System. (Excavator)